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DELINEATION OF CLAY LAYERS USING GROUND PENETRATING RADAR TO CHECK GROUNDWATER DEPLETION

K. K. K. Singh *

काफी बड़ी मात्रा में अध:तल अयस्क के उपयोग से स्थानीय भूमिजल सारणी विक्षुब्ध हो सकती है। अयस्क निष्कर्षण की इस प्रक्रिया से भूमिजल का नि:शेषण होता है। किन्तु ये बातें उस क्षेत्र की भूगर्भीय आकृति और खनन पद्धति पर निर्भर करती है। कुछ जगहों पर भूमिजल सारणी ऊपरी सतह से बहुत कम गहराई पर पायी जाती है, जबकि कुछ अन्य जगहों पर धरती का निचला तल अभेध चट्टानीय परत वाला है। हो सकता है कि भूमिजल सारणी इस परत के नीचे हो, और अभेध चट्टानीय परतों के नीचे भूमिजल होने के कारण अयस्क के निष्कर्षण के फलस्वरूप उन क्षेत्रों की जलीय व्यवस्था प्रतिकूलत: प्रभावित न हो। इस आलेख का उद्देश्य मृत्तिका की परतों और जलीय संस्तरों में भेद दिखलाना है, ताकि उन क्षेत्रों में जहाँ के अध:तल अभेद चट्टानीय परतों के बने हों, खुली खदानें शुरू की जा सकें। अध:तलीय भू-वैज्ञानिक परिदृश्य की गवेषण के बाद खुली खदानों में भूमिजल के नि:शेषण को परोक्ष रूप से रोकने में ग्राउण्ड पेनिट्रेशन राडार बहुत ही उपयोगी होगा।

INTRODUCTION

Opencast mining has, in some places, extended below the surrounding groundwater table. The mining may have an impact on the availability of groundwater resources, and this has become a great problem because the people in that region suffer from water scarcity. The lowering of the local groundwater resources is a phenomenon commonly associated with opencast mining (Brawner, 1986). However, this impact is dependent mainly on the geological characteristics of the respective area as well as the mining methods that are used (Karanth, 1990; Kresic, 1997; Soliman *et al*, 1997).

In some places the underlying strata are the groundwater table while in some places the underlying strata are impervious clay layers, which may be above the ground-water table. Due to the presence of the impervious clay layers above the groundwater table, extraction of ores will most likely not affect the surrounding groundwater table. The objective of this paper is to distinguish between the clay layers and the water-bearing strata so that one can go beneath the earth during mining in areas where the underlying strata are impervious clay layers. GPR plays an important role for delineation of the clay layers.

METHODOLOGY

Geophysical methods can give better solutions indirectly after locating the different problems in the mining areas (Maomayez *et al*, 1996; Cook, 1975). Among the geophysical methods, GPR is the most feasible technique for shallow workings (Singh, 2003). It depends on the emission, transmission, reflection and reception of an electromagnetic (EM) pulse and can produce continuous high-resolution profiles of the subsurface rapidly and efficiently (Benson, 1995; Beres and Haeni, 1991; Davis and Annan, 1989). It can provide more detailed pictures but has very limited depth of penetration in areas with conductive unconsolidated sediments, such as clayey soils.

A very short time impulse is generated at a very high frequency (25 MHz – 1 GHz) and radiated by an antenna, called a transmitter. When the signal encounters an anomaly, it is reflected and picked up by a receiver, which transmits it to a graphic recorder (Fig. 1). This is referred to as a "scan", or radar echo. The waves reflected by anomalies in the subsurface are observed successively with the regular movement of the antenna along each profile. The data are presented as a "time section". A record shows the total travel time for a signal to pass through the subsurface, reflect from an inhomogeneity, and return to the surface. The two-way travel-time is measured in nanoseconds (1 ns = 10-9 seconds). Determining the depth to a reflector involves using the following basic equations:

$$D = T . V / 2 \quad (1)$$

$$V = C / \sqrt{\varepsilon} \quad (2)$$

* Central Mining Research Institute, Barwa Road, Dhanbad-826001

where D = depth to the reflector, in m; T = two-way travel time, in ns; C = velocity of light in free space (0.30 m/ns); ε = relative dielectric permittivity, a dimensionless ratio; V = electromagnetic wave velocity, in m/ns.

The depth of exploration varies between 1 and 30 m for both natural soils and construction materials. The depth of penetration depends on the following (Olhoeft, 1986):

(i) the pulser voltage of the emitter,

(ii) the emitted wave frequency,

(iii) the electric properties of the subsurface materials (dielectric and conductivity),

(iv) moisture content.

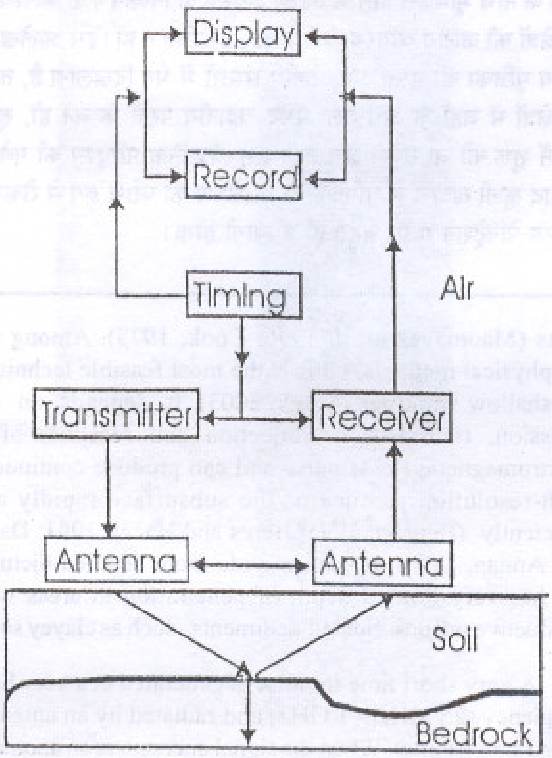

Fig. 1 : Block diagram depicting main components of a GPR system

RESULTS AND DISCUSSION

There are many geological structures/inhomogeneities which play very important roles during the extraction of any mineral either from underground or opencast mines. In the case of hydrogeological study, recognition of clay layer and water-bearing strata plays a very important role in that it foresees the problem posed at groundwater resources. GPR surveys were carried out at many sites where the underlying strata are clay layers and water-bearing strata, and the GPR sections obtained at those sites were corroborated by the existing borehole sections for confirmation of the different GPR signatures for clay and water-bearing strata.

The attenuation of GPR signatures is based on the reflected EM wave characteristics. The attenuation constant of clay is very high with respect to fresh water and other geological formations except seawater. Therefore, EM waves passing through clay are highly attenuated so that one cannot get layers (good reflection). In the case of a water-bearing zone, water bearing strata having higher attenuation values with respect to other geological materials except clay, can absorb EM waves, but in this case poor reflection zones (represented by dark lines with lower visibility) are observed due to high attenuation of EM waves in comparison to other geological formations except clay and seawater.

GPR surveys are carried out at many profiles on many locations. Only four profiles were selected where borehole data were available for corroboration. The GPR section along profile 1 (Fig. 2) shows good reflections (highlighted by thick dark black lines) up to 6 m depth which can be attributed to the presence of a solid layer. The reflections gradually fade below 6 m depth; this can be attributed to the presence of clay layer with moisture. To ascertain the GPR-run results (signatures) with actual subsurface conditions, the existing borehole litho-logs (BH2 & BH3) located at surface positions of 52 m and 142 m along this section respectively, were utilized. After correlation of the borehole sections (BH2 & BH3) with the GPR section, the solid layers are inferred to be sandy layers. Borehole section BH2 indicates the presence of a solid sandy layer (good reflections) down to depths of 5 m from the surface; after that, a clay layer (the absence of reflections due to highly attenuation of EM waves) is found. Similarly, borehole section BH3 indicates the presence of a solid sandy layer (good reflection) down to depths of 6 m, after which a water-bearing zone (poor reflections due to attenuation, but less attenuation with respect to clay layer) is confirmed at depths of 6 m from the surface. These borehole sections support the radar signatures of the GPR section (Fig. 2).

The GPR section along profile 2 (Fig. 3) shows good reflections, and the interpretation from this is that solid layers exist from the surface to the depth of 7 m only except at surface positions 0-65 m and 78-90 m, where solid layers (good reflections) exist down to depths of 3-5 m from the surface. Below this, water-saturated zones (poor reflections zone) and clay layers (absence of reflections) are present down to the depth of 17.5 m. Positions of borehole sections (BH4 & BH5) lie at the surface positions of 20 m and 70 m respectively on the GPR section (Fig. 3). After correlation of the borehole sections (BH4 & BH5) with the GPR section, it is inferred that sandy layers exist at depths of 3 m and 7 m from the surface; and below that, a clay layer and water saturation zones are found respectively. Borehole sections BH4 shows clay layers at the depth of 3 m and BH5 shows water-table layers at the depth of 7 m from the surface. Here, borehole data (BH4 & BH5) confirm the radar signatures of the GPR section along profile 2 (Fig. 3).

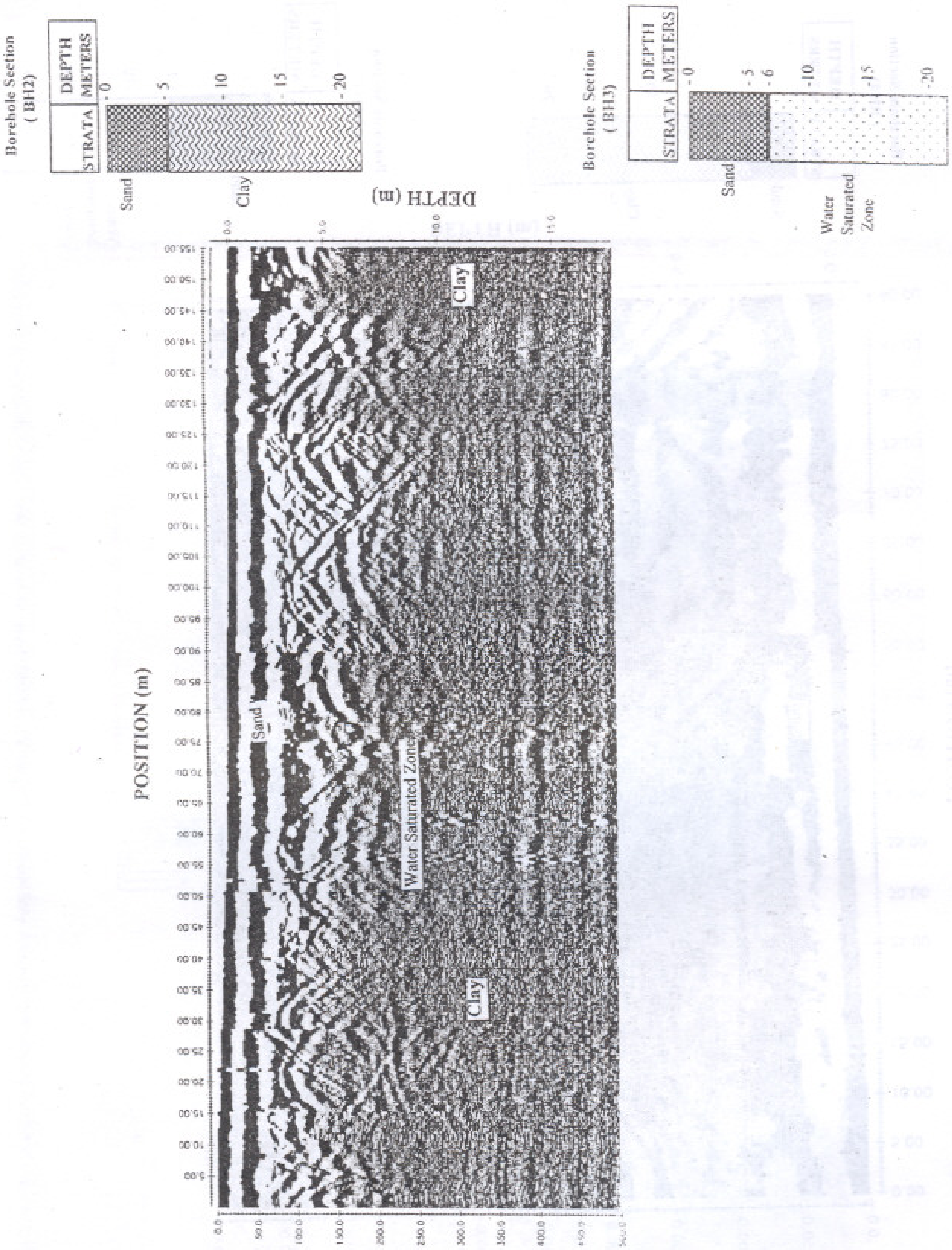

Fig. 2 : GPR section of profile 1 in which thick dark black lines indicate solid sandy layer. Poor reflections are indicative of water saturated zone, followed by absence of reflections due to clay layers. This is corroborated by borehole sections BH2 & BH3 at surface positions 52 m & 142 m respectively.

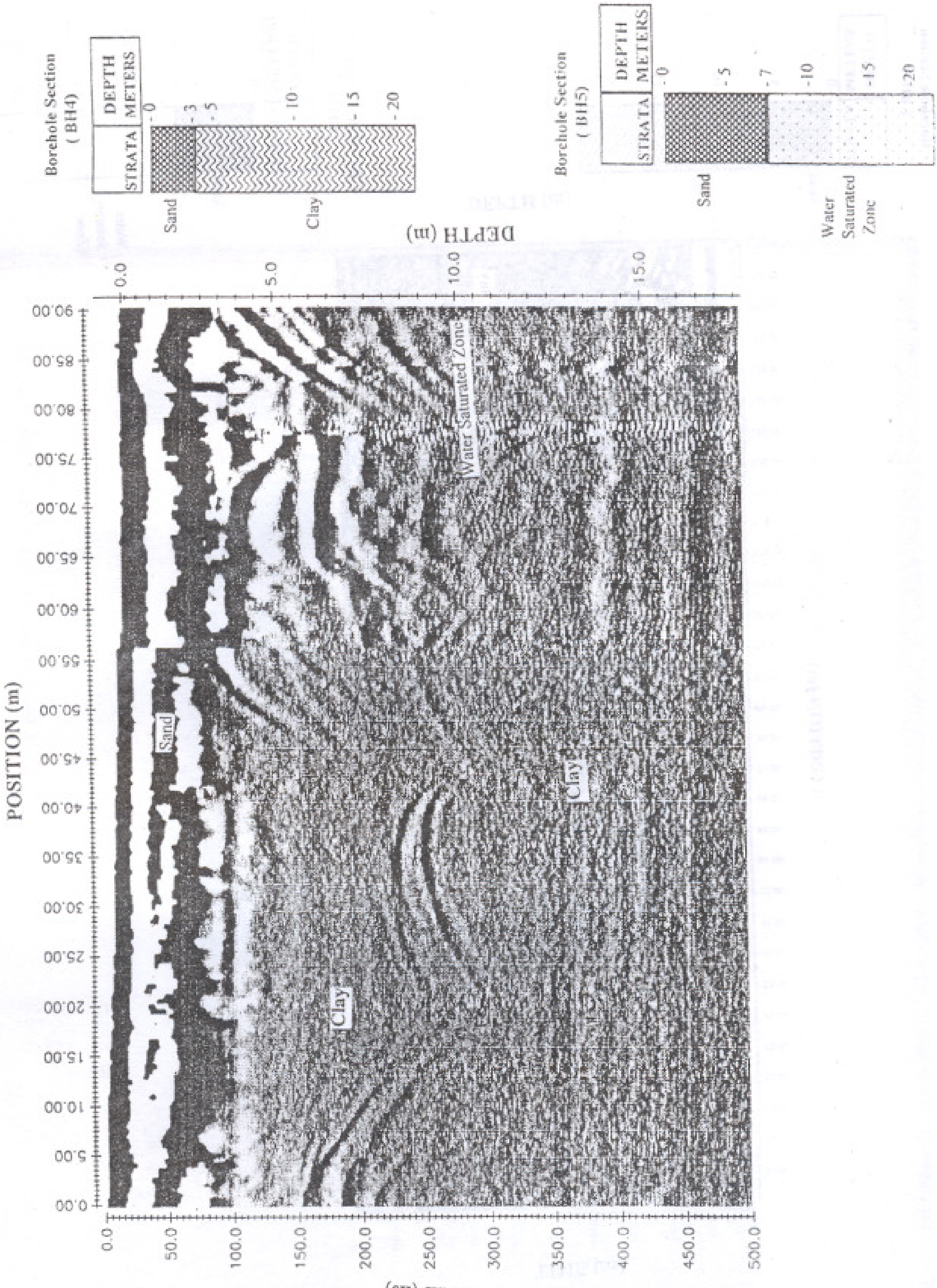

Fig. 3 : GPR section of profile 2 in which thick dark black lines indicate solid sandy layer. Poor reflections are indicative of water saturated zone, followed by absence of reflections due to clay layers. This is corroborated by borehole sections BH4 & BH5 at surface positions 20 m & 70 m respectively.

The GPR section along profile 3 (Fig. 4) shows good reflectors, interpreted as solid layers existing down to depths of 10-12 m. These layers are interpreted to be laterite layers when correlated with borehole section BH6 at the surface position 15 m of the GPR section. This correlation process applied for the entire length of the section. Here, water-bearing strata are dominant. This water-bearing zone is confirmed with the borehole section (BH6) available at the surface position 15 m of the GPR section from depths of 10 to 22 m (Fig. 4). In the case of the water-bearing zone, thick dark lines are visible, though they are not as clear as in the case of sold strata (good reflection). This is because of poor reflection due to the attenuation of EM waves in water-bearing strata.

The GPR section along profile 4 (Fig. 5) shows good reflections, represented by dark lines and interpreted as solid layers being present at depths varying from 7 to 15 m from the surface, except at one surface location (60 m) where solid layers extend from the surface to 22 m depth. Water-bearing zones (poor reflections) exist at depths varying from 7 to 22 m at surface positions 16 to 59 m. In this section, the water table is also situated at a very shallow depth of 7 m. Solid layers (good reflections) are interpreted as laterites, and below that, water-bearing zones (poor reflection) are interpreted to exist, when the GPR section is correlated with borehole section BH7 available at surface position 32 m of the GPR section (Fig. 5). Here, it may be concluded that the mining process can deplete the

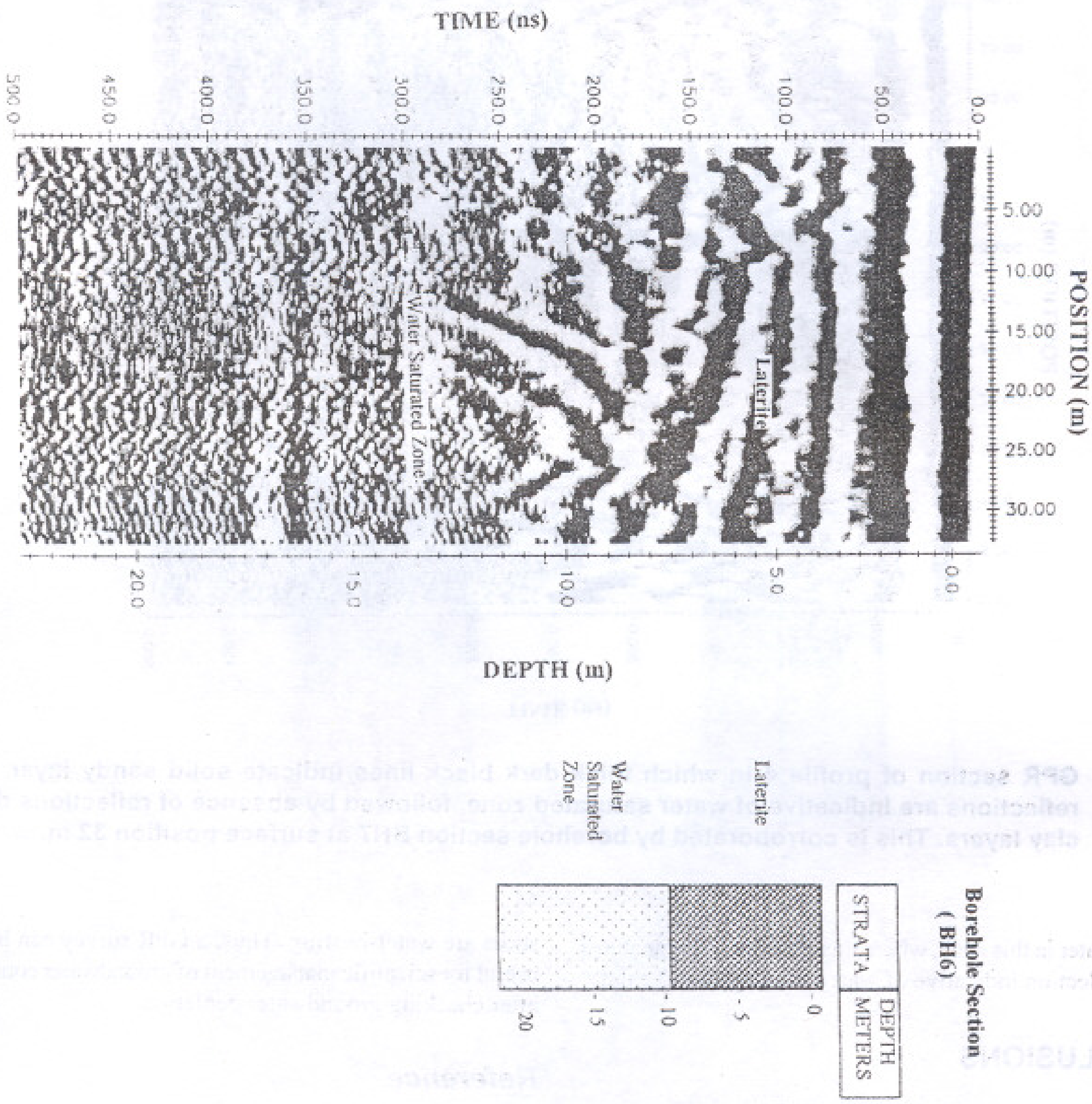

Fig. 4 : GPR section of profile 3 in which thick dark black lines indicate solid sandy layer. Poor reflections are indicative of water saturated zone, followed by absence of reflections due to clay layers. This is corroborated by borehole section BH6 at surface position 15 m.

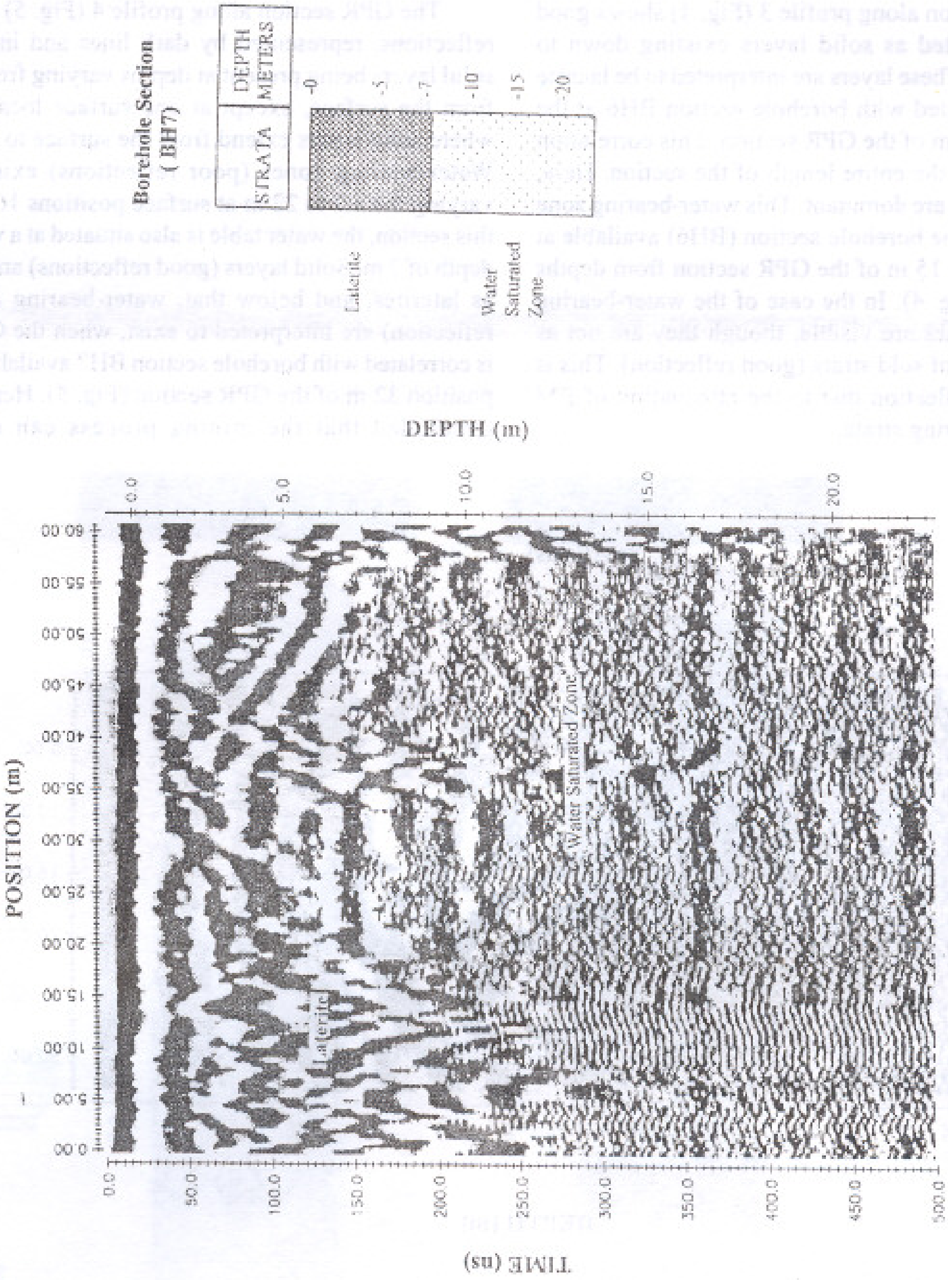

Fig. 5 : GPR section of profile 4 in which thick dark black lines indicate solid sandy layer. Poor reflections are indicative of water saturated zone, followed by absence of reflections due to clay layers. This is corroborated by borehole section BH7 at surface position 32 m.

groundwater in this zone, where this type of GPR signatures (poor reflection indicative of water-bearing strata) exist.

CONCLUSIONS

It can be concluded that GPR can play a very important role in the recognition of clay layers and water-bearing zones. Mining will not affect the groundwater table of those areas where the underlying strata are impervious clay layers above the groundwater table, whereas the groundwater table will be affected where the underlying strata are water-bearing. Thus, a GPR survey can be very useful for scientific management of groundwater conditions after checking groundwater depletion.

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